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Review on Clean Milk Production and the Factors Affecting Milk Quality

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Milk is considered a delicious and complete food enriched with a variety of nutrients worldwide. Ensuring its hygienic standards and quality is indispensable to both public health and food safety. As a frequently utilized product, it is essential to maintain its hygiene and cleanliness. If it is contaminated with microbes, then it may cause severe and deadly infections to human beings. It is extremely susceptible to microbial growth. Several factors have a key role in contamination of the milk, comprising animal hygiene, shed design, bedding of the shed, equipment and workers. Animals soiled with feces and mud as well as udder lead to poor quality milk. Similarly, if the shed is not properly designed, there is pooling of water and mud, which also deteriorates milk quality. Moreover, improper washing of hands of the worker and milking method may cause injuries to the teat and also infection to the udder. Pre-milking and post-milking measures, including equipment sterilization, udder disinfection and proper milking techniques play an important role for clean milk production. It can be concluded that strict hygiene protocols during every step of milk production are vital for maintaining premium quality, uncontaminated milk and protecting public health. However, negligence at any stage leads to poor quality of milk and health issues.
Keywords: Dairy animals, milk contamination, milk production, public health, quality control.

INTRODUCTION

***Clean milk production*:** Clean milk production relates to the protocol of obtaining milk free from contaminants, such as pathogens, extraneous matters and toxins, while sustaining its fundamental nutritional composition. Quality milk is ensured by providing clean feed and maintaining hygienic measures in the environment (Suranindyah *et al.*, 2015). To ensure good milk quality, the teat and teat orifice should be washed and cleaned with cloth or clean with direct use of an antiseptic solution (Jones, 1998). There should be no coliform bacteria in the milk for good quality milk. Methylene reduction test (MBRT) should be performed no longer than 5 hours (Barbuddhe *et al.*, 2008). In small dairy farming, manure management is poor, so there is a need to make measures for the prevention of milk contamination (Suranindyah *et al.*, 2015).

***Importance of clean milk*:** Nowadays, consumption of raw milk has increased, leading to the *chances of infection in humans due to contamination with* a myriad of *pathogens* (Claeys *et al.*, 2014). Milk is mostly contaminated with pathogens, mainly originating from animal-related factors (mastitis can increase bacterial load) or environmental (manure, soil and water can introduce bacteria) during milking or storage of milk. The infection is differentiated into endogenous, which is transferred from the bloodstream or the mammary gland and cross contamination, which is transmitted through feces, the skin or the environment (*Escherichia coli*). Pathogenic microorganisms including *Salmonella spp.*, *Escherichia coli* and *Listeria monocytogenes* may exist in contaminated milk, leading to health complications. Milk quality can be determined by using various parameters such as the amount of *Enterobacteriaceae*, number of coagulase-positive *Staphylococcus aureus*, total bacterial count of some species, e.g. *Salmonella*, *Campylobacter* spp. and *Listeria monocytogenes*. Most fatal human pathogenic verocytotoxin-producing *Escherichia coli* (VTEC) and *Streptococcus* spp. are also present in raw milk (Verraes *et al*., 2014). The *E. coli* strain O157:H7 is also found in raw milk (Muehlherr *et al*., 2003). *Streptococcus agalactiae* (Abdurahman *et al*., 1995) *Streptococcus equizooepidemicus*, *Brucella abortus* (Capparelli *et al*., 2009) and *Coxiella burnetii* have also been isolated from raw camel milk (Rahimi *et al*., 2008).

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Mycobacterium avium sub spp. *paratuberculosis* and *Mycobacterium bovis* have also been detected in raw buffalo milk (Capparelli *et al*., 2009). To this end, clean milk production and hygienic measures are essential to maintain milk quality and prevent human beings from such infections. Moreover, brucellosis and tuberculosis are the zoonotic diseases that are too much fatal for human beings. Brucellosis causes undulant fever in humans so, clean milk production is of extreme important.

***Factor affecting milk quality*:** There are following factors that affect the quality of the milk that are described below:

***Factors related to shed design and environment*:** Most important environmental issue of dairy farm is production of manure which pollutes water on ground even under ground water. The use of fertilizer and pesticides for better production of fodder and crops also contaminates the soil as well as water. These factors also contribute to contamination of milk.

***Manure waste*:** Manure waste represents a valuable source of nutrients. However improper storage and land application of manure and slurries results in serious pollution of surface waters and groundwater, potentially contaminating drinking water supplies.

***Milk contamination*:** The contamination of milk with antibiotics has been an issue of concern. This is due to the overuse of antibiotics for treatment of cattle diseases, particularly mastitis. It has been brought under control in most countries with developed dairy industries, through strict limitations on the use of antibiotics, regular testing of milk for antibiotic residues, rigorous enforcement of regulations, and public education.

The design and management of a housing system is influenced by how long the cows will use it e.g. all winter or for twelve hours a day it must provide a clean, dry and comfortable environment that does not compromise cow's health, welfare, comfort or production. When selecting a housing option, it is important to be clear on the purpose of the building. There are many factors to consider the suitability of the facility to house lactating and dry cows, the local climate requirements for housing during hot and wet periods, access to resources such as water and a sustainable supply of bedding material, animal health and welfare implications, effluent management systems and intended use for old bedding, effluent and potentially separated effluent products. Cows housed on hard surfaces, such as concrete, solid or slatted floors and river stones have increased the incidence of lameness, stiffness and agitated behavior, decreased lying times and dry matter intakes as well as reduced body condition scores. Additional bedding material can be added to hard flooring to create comfort. Keeping the lying area dry and clean is essential for comfort and health of animals. Good bedding helps to minimize soiling and improves animal comfort. Where mats or mattresses are fitted, absorbent bedding material should also be used. All passageways, loafing areas and cubicles should be kept free of accumulations of dung, slurry and stale feed. Good design of the lying area, stocking rate, drainage, management of the lying surface and ventilation all go toward keeping lying surfaces dry (Bailey, 2017**)**. The climate in tropical areas is categorized into three climatic seasons (MD, 2002) winter (November to February), summer (March to June), moonsoon (July to October).

Mostly rainfall takes place in Pakistan in moon soon season (July to September), as a result of this farmer face problem in controlling the mud in resting area of cattle, so it becomes difficult for the farmer to keeping clean that area in particular keeping clean udder and teats during this period. Animals are soiled with mud and become more prone to infection. In this season animals mostly suffered with mastitis (Gonzalez *et al*., 1990) as well as temperature and humidity increases, that increase chances of mastitis. More chances of mastitis are due to heat stress, which compromises the overall immune response of the body (Holub, 2002). When animal udder is soiled with feces and mud, both are considered an environmental source of contamination which leads to unhygienic milk (Pankey, 1989). Housing must be managed to avoid the soiling of the animals.

Dirty udder and teats increase the duration of pre-milking preparation (Reneau *et al.*, 2003). A close association exists between udder contamination and udder infection (Schreiner and Ruegg, 2003; Reneau *et al*., 2003; Ellis *et al*., 2007).

The design of the shed plays an important role in milk cleanliness and cattle health. It can minimize the risk of contamination from dust, flies, birds, and animals. There is a high risk of contamination in an open milking area if birds get access and there is more dust in adjacent places.

Water is not fully drained from impervious floor. Pooling of water in shed cause soiling of udder that further contaminates the milk. Standing area should be inclined so removal of water should be easy and there should be no pooling at milking parlor. All these factors contribute towards unhygienic conditions. Housed animals may have higher exposure to communicable diseases, whilst extensively maintained animals are more prone to parasitic infections. Animals introduced from different locations may be vulnerable to endemic diseases in the new location due to lack of previous exposure and therefore, the development of immunity (Verraes *et al.*, 2016).

***Factors related to dairy animals*:** When an animal is soiled with manure, it causes irritation and sub-clinical infection (Tancouse, 1986; Sogstad, 2007). The cleanliness of cattle has a great influence on clean milk production, maintaining thermoregulation and supporting health conditions (Huges *et al.*, 2004). The soiling of the cattle often results from diarrhea that occurs due to some infectious agent or inappropriate feeding with low fiber content. Animal cleanliness on farms is associated with various factors like physical condition,

management, feeding, health and production (Reneau *et al.,* 2003; Ruud *et al.,* 2010).

Management factors are routine scraping of mud, use of bedding material, duration of replacement of bedding, clipping, washing and brushing (Herlin, 1997; Lowman *et al.,* 1997; Davies *et al.,* 2000). All these factors are responsible for unhygienic milk production. Before milking, the cleaning of the floor, feed and water trough along with washing of cows decrease the source of infection. Moreover, drying the udder with a clean cloth also reduces the potential source of contamination. Cleaning the teat at milking also helps to remove manure and pathogens that cling to the mammary gland. Improper milking hygiene and lack of use of disinfectant post-milking are associated with a high prevalence of subclinical mastitis. Bacterial pathogens particularly, coagulase-negative *Staphylococci* were found as a result of poor milking hygiene.

This type of bacteria is commonly colonized in the teat end and teat canal. Discarding first milk flow seemed helping to achieve this quality level by reducing the number of bacteria in milk (Prosser *et al*., 2008). Raw milk itself is fairly sterile but some environmental contamination (bacteria from feeds, feces, bedding material, soil) is inevitable (Lemma *et al.,* 2018). The bacterial count of the milk is increased by poor milking practices, dirty environment, lack of cooling technology and poor animal health (Welearegay *et al*., 2012). Mastitis affected milk is not sterile as, depending on the stage of infection and the specific organism, pathogenic bacteria are shed in the milk from the infected teat (Lemma *et al.,* 2018).

***Factors related to milkmen/dairy workers*:** Generally, issues related to physical health and societal sustainability are lacking in dairy farm models. Insufficient worker physical health, i.e. disability, in dairy farming is caused by poor working conditions. The main causes of disability are musculoskeletal-related disorders (back, neck/upper extremity and lower-extremity) and injuries (Hartman *et al.,* 2003). Risk factors for disability due to injuries and disorders can be subdivided into farm characteristics, psychosocial variables and personal characteristics of the farmer (Hartman, 2004).

Poor cleaning of floor, dusty and soiled animals lead to poor quality of milking. Washing hands at the time of milking, no drying of udder after washing and discarding first milk strip, all these practices cause contamination and odor which is easily absorbed in the milk. Wetness of udder and milker hand also increase microbial load in milk (Suranindyah *et al.,* 2015). Use of bare hand for drying of udder is not sufficient (Welearegay *et al*., 2012). Wet teat allows skin and environmental bacteria to have easy access in mammary gland. There is a restriction on the utilization of large amounts of water for cleansing of teat (Jones, 1998). It was obtained by that wet milking was a major cause of high initial of bacterial count. This might be due to the dripping of surplus water that contained bacteria from udder into milk. The use of post milking disinfectants will control this type of bacteria and sub-clinical mastitis, proper cleaning and disinfection of cow's udder and equipment reduced coliform count to be less than standard (Mdgela *et al*., 2009). During milking, farmers were observed cleaning the cow's udders and teats with water and using milking salve before milking to prevent cracking of the teat skin (Islam *et al.,* 2009). The water and cloth used for cleaning the udder were often dirty and the same cloth was used repetitively on all the animals. The use of inappropriate methods of milking causes cracks on teats skin. Farmer are seen using sieving the milk to remove dust and debris (Mdgela *et al*., 2009).

***Factors related to feed and water*:** The main cause of low milk production of our dairy animals is the poor availability of nutrients in quality as well as quantity (Sarwar *et al*., 2002). In Pakistan, crops, shrubs, grasses and agro-industrial wastes are being utilized to fulfill nutrient requirement of dairy animals. It has been estimated that livestock obtains 51%, 38%, 3%, 6% and 2%, respectively, of their required nutrients from green fodder, crop residues, grazing rangelands, post-harvest grazing, cereal by products and oilcakes/meals (Mattick *et al.,* 2003). The scarcity of feed and fodder in the country is deteriorating the production potential of dairy animals. The situation has further been worsened due to continuous increase in the population of dairy animals. Low production of forages per acre has further adverse effect on the availability of nutrients (Sarwar *et al*., 2002) and there is no use of silage or concentrates. Contaminated ground water, ever increasing unused manure (Sarwar *et al.,* 2002). The quality of feed is becoming poor due to bad storage practices. During storage, a lot of biochemical and enzymatic reactions take place by itself or by some other causative agent like pest, rodents and microbes. These changes deteriorate the feed quality and quantity of feed. Feeding animals with such feeds is responsible for the poor health of the animals.

***Factors related to utensils*:** Pathogens can be transferred to food from utensils that are not properly cleaned. Since some pathogenic microorganisms can survive outside the human body for considerable periods, poorly sanitized utensils could be a direct or indirect source of food-borne illnesses (Parker, 2005). The occurrence of foodborne illness risk factors in retail food establishments mentioned the need for improvement in the sanitization process for food contact surfaces (FDA, 2004). The efficiency of manual dishwashing resulted in fluctuations in removing microorganisms from utensils. This efficiency could be affected by the number and sizes of utensils, the time designated to clean them, the initial microbial load, the quality of the detergent, the nature of the organic matter on the utensils, washing temperature, the attitude of the employee and the complexity of the utensils to be cleaned (Montville *et al*., 2002; Mattick *et al.,* 2003). The use of scrubbing sponge for the removal of particles from utensils may vary, especially when the utensils may be required to wash in a shorter period. Organic matter, including

food residues, is known to protect bacteria from direct contact with the heat or detergents used in dishwashing operations. Use of clean utensils during animal feeding helps to maintain animal health. To maintain the animal house utensils clean, prewash the utensils with clean, cold water. This removes much of the dirt and should be carried out immediately after the product has been removed. Wash the equipment with cold water, following warm water (50℃) and detergent to remove fatty material. If the equipment is washed thoroughly with water much less detergent is required in later stages, also ensure that it is chemically clean. The equipment is cleaned by hand it should be scrubbed thoroughly using the detergent solution. Detergent cleaning also reduces bacterial numbers on the equipment.

***Clean milk and public health concerns*:** In most developing countries, numerous dairy programs have been implemented to increase milk production (Bonfoh *et al*., 2006). But they have not always included milk hygiene. Instead, the objective of most of the dairy development programs have been to increase milk yield for human consumption in order to fulfill the demands of growing population

High bacteria count in raw milk decreases the shelf-life of liquid milk and other dairy products. Therefore, raw milk hygiene also affects dairy economy (Millogo *et al*., 2008). Milk hygiene in the dairy chain is uncontrolled, and pasteurization is not commonly used as a quality management method (Millogo *et al*., 2008).

The public health concerns regarding bovine mastitis are mainly related to the occurrence of both different pathogens and antibiotic residues in milk for human consumption. *Staphylococcus aureus* is probably the most important species in this respect. In case of consumption of raw milk there can be a real hazard, the main threat being the fact that about 10% of mastitis *Staphylococci* are known to be producers of enterotoxin (Heeschen *et al*.,1985). *Staphylococcal* enterotoxins can be regarded as a public health hazard within the bovine mastitis. *Escherichia coli* species, a specific verocytotoxigenic strain may cause hemorrhagic colitis (Pennington, 1997; Leclerc *et al*., 2002). The most important one is the enterohaemorrhagic type *E. coli* (EHEC) O157:H7 (Leclerc *et al*., 2002). Escherichia coli O157:H7 is an emerging cause of food-borne illness and is now considered as an important human pathogen (Pennington, 1997). Transmission of coliform organisms potentially including *E. coli*O157:H7 occurs through the ingestion of raw milk (Quinn *et al*., 2000). *Bacillus cereus* produces two distinct forms of food poisoning, the diarrheal syndrome caused by heat-stable enterotoxin and emetic syndrome involving a very heat-stable enterotoxin (Quinn *et al*., 2000) *Enterococcus faecalis* has been suspected as a causative agent of foodborne illness (Stiles, 1989). The presence of antibiotic residues in milk is of public and economic concern, because of the risk of impaired health in persons who consume the milk from treated cows (Sharif and Muhammad, 2008).

***HACCP system for milk safety and quality control*:** Hazard Analysis Critical Control Point (HACCP) is synonymous with food safety management, a system which identifies, evaluates and controls hazards which are significant for food safety. Hazard as used in the HACCP system is defined as "a biological, chemical or physical agent in, or condition of food, with the potential to cause an adverse health effect". Critical Control Point (CCP) is "a step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level"

***Microbiological hazards*:** Milk is frequently contaminated by feces from soiled animals, especially teats, udders and tails. Poor milking practices, soiled hands, inadequately cleaned and disinfected equipment (including bulk milk tanks) and failure to clean and disinfect teats before milking further increases the chances of contamination (Bonfoh *et al*., 2006). The risk of contamination can be reduced by properly cleaning animals and equipment. All animals should be kept clean. All lying areas should be of sufficient size and should be kept clean and dry. Milk from each animal must be examined for physical/chemical/ organoleptic abnormalities and where abnormal milk is detected, this milk must be discarded. Teats, udders and adjacent parts must be cleaned before milking. Milk contact surfaces (hands and milking equipment) must be appropriately cleansed and disinfected immediately after each milking. All equipment must be kept clean and in good condition. Cows with a clean, trimmed tail will attract fewer flies. Flaming of udders and/or clipping of flanks, bellies and udder reduces the amount of soil or feces which can adhere to these areas. Remove dirt manually and encourage grooming with cow brushes. Clean animals are more likely to remain disease free and at milking time, are less likely to contaminate the milk with harmful bacteria. Consider altering diets to minimize loose dung (Sharif and Muhammad, 2008)

***Managing hygiene for clean milk production*:** Hygiene is key to determine whether the milk is clean or not. Every activity which is done at the farm should be geared towards achieving high standards of hygiene. There are critical points of contamination such as cow teats. Most bacteria take advantage of this window and fall into the milk during milking. The cow may also introduce the pathogens into the milk by dipping its tail or foot into the milk vessel during hand milking. Dirty workers may also introduce pathogens into the milk. Smoking in the milking area can cause an undesirable tobacco odor in the milk. Similarly, workers should also avoid the usage of perfumes at the time of milking as odors can transfer to the milk. The adherence to high standards of hygiene will help to reduce contamination and produce clean, safe milk (Millogo *et al*., 2008).

***Measures to improve hygiene at the farm*:**

- ✓ Do not sweep or clean the floors during milking as that may introduce pathogens into the milk.

- ✓ The milkers should be in perfect health and free from communicable diseases. They should use head/beard gear to cover their hair or trim it to avoid contamination. Their nails must be short, and they should wear protective gear while working. They should not smoke near the milking parlor, and they should not spit or blow their noses while milking.
- ✓ The milker must wash hands with soap and rinse adequately before milking. Hands should be dried with a disposable towel to eliminate the chances of re-contamination. The use of hand dryers is not recommended as a warm environment may encourage microbial growth.
- ✓ Properly clean the udder before milking using potable water and a clean towel. Soap is discouraged because it may get into the milk. Secure the animal in the crush and use a kick stopper to prevent the animal from spilling the milk or dipping its leg into the milking can. While using a machine for milking, secure the teats properly to avoid letting air into the system.
- ✓ Every milking session should last an average of seven (7) minutes in high yielding animals. Desist from the practice of dipping your fingers into the milk to wet the teats. In fact, avoid wet milking if you want to guarantee your milk hygiene.
- ✓ Dip the teats into a bacteriocidic after milking to avoid bacterial infection. Give the animal some feed or ensure it remains standing for the next several minutes until the teat canals close. If they sleep in dirty places immediately after milking, bacteria will have easy access into the udder.
- ✓ After milking, strain the milk through a clean strainer/muslin cloth to remove debris and other foreign matter. A centrifugal separator removes the soil very efficiently. Clean the strainers as regularly as possible. Clean the muslin cloth using detergents and dry it.
- ✓ Immediately after milking, weigh the milk and cool to avoid multiplication of bacteria. The milk storage room should not house other chemicals or grains. Deliver the milk to the dairy in the morning or evening to avoid heat of the day. Use a covered vehicle/means of transport to avoid direct sunlight.
- ✓ Use seamless aluminum or stainless-steel cans, as they are easy to clean and do not harbor pathogens. Seams create a fertile ground for bacterial multiplication.
- ✓ Use clean and potable water at the farm because it is an easy route for contamination since you will be using a lot of it.

***Milk cooling for clean milk production*:** Bacteria replicate rapidly under warm temperatures. If the milk is not being processed immediately, it must be chilled to arrest bacterial activity. Chilling will maintain the quality of milk before it reaches the dairy plant. The cooling can be achieved through various means. The most obvious one is refrigeration. However, not every farmer has refrigeration facilities. In such cases, milk can be cooled by a home-made charcoal cooler or using chilled water.

Cooling the milk to less than 5℃ immediately after milking is recommended. Delayed cooling may cause acidity and spoilage of the milk, which cannot be reversed by refrigeration. If there is no cooling facility at the farm, deliver the milk to the dairy within two hours after milking to avoid spoilage.

***Conclusion*:** In conclusion, it is stated that ensuring milk hygiene is vital at every stage of production for successful dairy industry and public health. Practices like proper milking protocols, hygiene measures and immediate cooling are important for the prevention of microbial contamination and spoilage. Implementing HACCP principles and practices can result in clean and safe milk production. Future efforts should be made to improve on-farm cooling facilities, to enforce hygiene regulation and awareness among dairy farmers for the safety of consumers.

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Policy referred: 1. National Dairy Development Policies (Country-specific),2. World Health Organization (WHO) Guidelines,3. Codex Alimentarius,4. World Organisation for Animal Health (WOAH/OIE) Standards.

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